# OPTICAL VARIABILITY AND BOTTOM CLASSIFICATION IN TURBID WATERS

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## LONG-TERM GOALS

The development of an optical methodology, valid for Case II coastal waters, for the remote classification of the sea bottom including sediment type (calcareous/quartz sand, clay, mud), benthic flora (benthic diatom and algal mats, seagrasses, green and red macrophytes), and bottom structure (reef, rock). The methodology will exploit elastic and inelastic spectral information as well as 3-dimensional size, shape, and texture information determined by optical methods.

## OBJECTIVES

The deconvolution of the components of the underwater and water-leaving light fields in coastal waters. The determination of feature vectors, including 3-D morphology, which hold information unique to different bottom types and structure for use in an automatic classification strategy.

## APPROACH

This project utilizes the Bottom Classification/Albedo Package (BCAP), a suite of optical instrumentation developed under previous ONR funding, to acquire the hyperspectral database required to deconvolve the components of the underwater and water-leaving light fields. *In situ* instrumentation includes a 512-channel upwelling radiometer, a 512-channel downwelling irradiometer, two, 6-channel, intensified bottom cameras, a dual-laser, optical altimeter/chlorophyll probe, instrumentation to measure attenuation, absorption, and fluorescence at various wavelengths, and a real-time microtopography assembly. The package is configured for deployment on either a remotely operated vehicle (ROV) or an autonomous underwater vehicle (AUV). A real-time, three-dimensional microtopography sensor package is under development using a bi-static laser-line imaging system where deviation of the projected line from the position in the image it would occupy at mean altitude is porportional to the relief of the bottom/object. Accurate range data to various bottom components is required for albedo correction for path attenuation, and 3-D shape assists in bottom and object classification, especially for turbid waters.

## WORK COMPLETED

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- Solar-stimulated bottom fluorescence (685 nm) was sufficient to distinquish man-made objects (non-fluorescent), using an intensified video camera from both our ROV and our Ocean Voyager II AUV.
- Bi-static, laser-line, 3-D imagery were collected for corals, sand waves and man-made, mine-like objects using an ROV platform.
- A real-time, micro-topography/range system has been designed and constructed for AUV deployment is housed along with a Pentium-CPU, single board computer in a pressure housing. Ethernet data output rates allow real-time data display of up to 700 scan lines per second. A 532 nm, 65 mW, frequency-doubled, diode-pumped laser, fitted with a non-gaussian line generator, is coupled to the microtopography system using a 1m bi-static separation from the camera and an adjustable viewing angle. Tests on our ROSEBUD ROV are underway.
- A 34-foot LOA underwater-vehicle-support vessel, the R/V Subchaser, has been designed, constructed, outfitted and utilized near Marathon Key, Florida for seven days in June, 1997, deploying the ROSEBUD ROV and the Ocean Voyager II AUV.
- A transom-mounted video camera (Sony XC-777) for bottom imaging and a ORE Trackpoint LXT acoustic tracking unit operating as part of a DGPS-based Integrated Positioning System have been integrated and utilized on the R/V Subchaser (Peacock et. al. 1998).
- All mechanical and electronic systems aboard the ROSEBUD ROV have been overhauled/upgraded
- The Ocean Voyager II AUV host computer hardware and LONWorks operating system software have been upgraded to Ocean Explorer class standards by Florida Atlantic University. In addition, the vehicle has been formally transitioned to USF by FAU for use by our group.
- A u-frame extension for the deployment/retrieval of underwater vehicles on the R/V Subchaser has been designed, constructed and utilized with both the OV-II AUV and the OEX Magellan AUV.
- A Doppler Velocity Log (DVL) unit has been identified (ORE Navigator) and is being acquired. The DVL is deployed on the underwater vehicles and secures acoustic 3-dimensional “bottom lock”, significantly enhancing precision positioning capabilities.
- “Spares” kits for all in situ systems for the 1998 Bahamas field excercizes are being provisioned.

## RESULTS

Due to the high attenuation of 685 nm radiation by water, little solar radiation at that wavelength is reflected from below a few meters of depth. However, blue-green radiation penetrated deeply in the ocean, stimulating bottom fluorescence at 685 nm to at least 20 m depth. High-contrast, NBP imagery of non-fluorescing objects against the natural, solar-stimulated (fluorescing) background were produced for depths from 6 – 20m. Water column conditions limiting this phenomenon are being investigated.

A bi-static, laser-line imaging system on ROSEBUD has provided micro-topography of the bottom and of bottom objects with 1 cm resolution in three dimensions. It is not, however, a real-time system. A real-time, bi-static laser-line system has provided proof-of-concept, range and topography information at 1 cm resolution in our flume (Fig. 1) and is being adapted for ROV/AUV deployment.

## IMPACT/APPLICATIONS

Solar-stimulated fluorescence imagery of the bottom can be acquired in any area where the depth is sufficient to effectively quench 685 nm reflected solar radiation and where blue-green radiation penetrates to stimulate 685 nm fluorescence. A parameterization of the effective operational environmental variables is being completed. The significance is two-fold: first, since the bottom is the source, the imagery acquired is free from the backscattered path radiance generally associated with contrast degradation in underwater imagery; second, animals and man-made objects do not, generally, fluoresce at 685 nm. This makes possible the visualization of bottom objects which may not be readily

apparent using either active or passive reflection (elastic) imaging techniques.  Applicability ranges

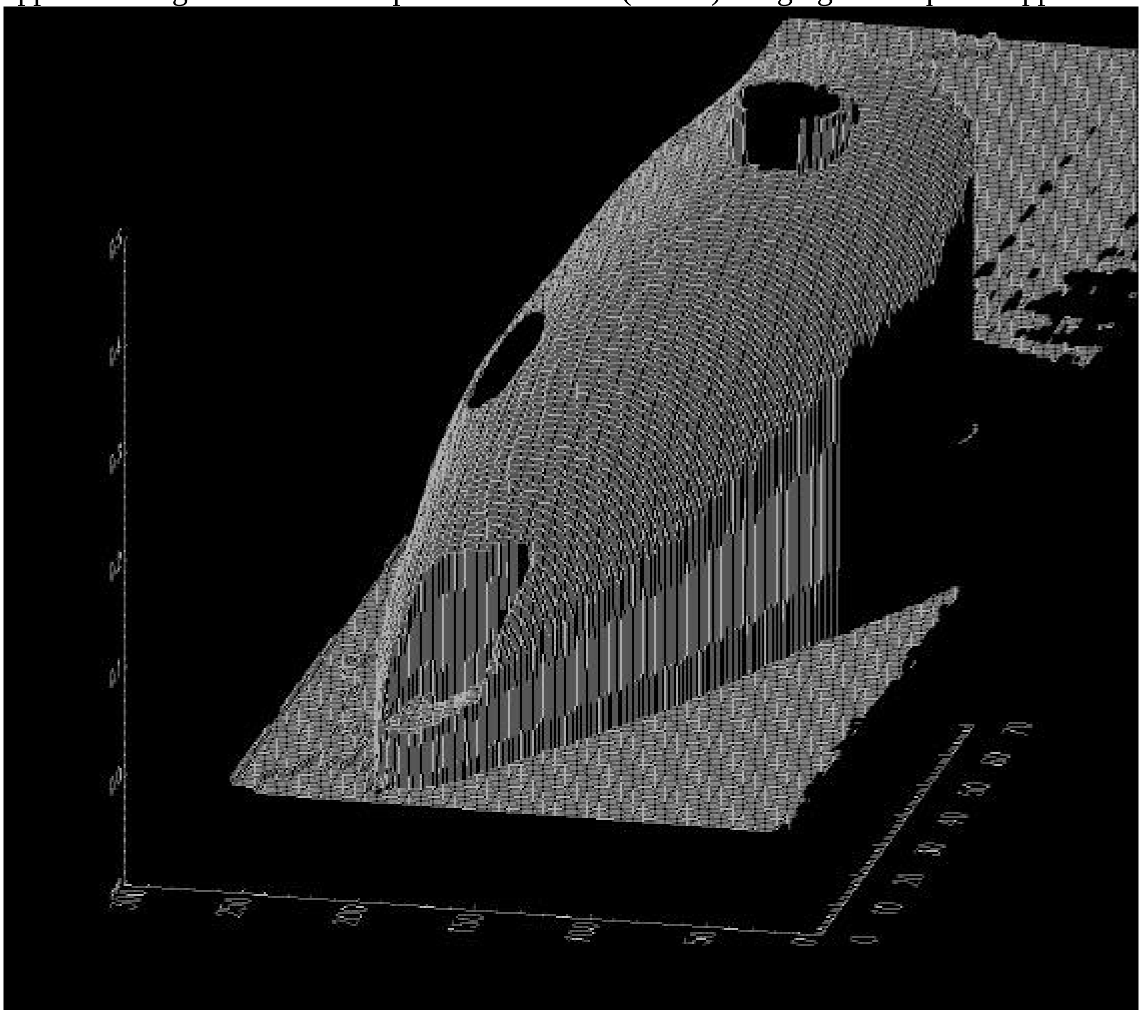

Figure 1. Top: A micro-topographic image map of an OEX AUV nose cone in the USF flume. Scale for height above bottom is in meters, while the cross-track and downtrack scales are in pixel units convertible by look-angle and sensor speed information, respectively, to distance in meters. Left: Cone shown in a photographic image.

from assessment of the standing stock of corals and sponges to underwater mine detection.

Real-time, high-resolution, micro-topography also has diverse potential applications. The most obvious of these is to provide the range information required to correctly interpret actively or passively stimulated fluorescence imagery. Other applications include coral biomass quantification, sandwave analysis, and bottom type/structure/object classification. Real-time 3-D imaging will be achieved from AUV-deployed systems via RF-ethernet transmission from a surface-towed float or by direct, underwater, optical communication.

## TRANSITIONS

The Ocean Voyager II AUV has been upgraded to OEX hardware and operating system standards and successfully transitioned from Florida Atlantic University (prototype engineering mode) to USF (operational scientific mode).

## RELATED PROJECTS

This project benefits from an association with the ONR project Coastal Benthic Optical Properties (CoBOP) and with Florida Atlantic University Ocean Engineering program. CoBOP field excercizes allow the opportunity to deploy hardware systems developed under this funding to image bottom structure/objects while benefitting from significant ancillary data collected by other CoBOP investigators.

Inversion of a model (funded through ONR/CoBOP and NASA) utilizing remote sensing reflectance provides bathymetry and water optical properties.

Co-operative relationships also exist between the AUV and AUV-sensor-development program of USF and Florida Atlantic University.

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